

In-situ stress measurement during aluminum corrosion in alkaline solutions

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ABSTRACT

Stress Corrosion Cracking is the mechanical degradation of metal in corrosive environment and it is characterized by crack growth during corrosion of metals in the presence of external stress. The synergism of corrosion and mechanical degradation in stress corrosion cracking is not yet well understood at the fundamental level. Improved mechanistic knowledge of SCC is needed to identify the important microstructural and material property changes accompanying the initiation stage of cracking that are precursory to failure [1–3]. Using high resolution in situ stress measurement, we report the corrosion-induced tensile stress generation, leading to plasticity during the Al corrosion in alkaline solutions. 1-mm thick 5N Al sheets or 25- μ m thick 5N annealed Al foils attached to Si wafers were exposed to different concentrations of NaOH solution. Curvature interferometry was utilized to monitor the curvature changes in the sample during the NaOH exposure. The force per width can be interpreted as the integrated stress through the sample thickness. High resolution of curvature interferometry enables us to monitor the stress during extended period of corrosion of thick metal samples [4]. Evolution of surface morphology in NaOH solution was characterized using Fast Fourier Transform analysis of the SEM images. Stress measurements were performed on samples with different flow stresses in order to identify the influence of plastic deformation on the reaction-induced stress fields. Stress measurements showed buildup of tensile stresses when aluminum samples are exposed to alkaline environment. In-plane stress increased approximately linearly with time for the first 15 min. Initial rate of increase of in-plane stress product did not depend on the pH or metal dissolution rate. After the initial buildup, the stress reached a plateau value. In experiments performed at different NaOH concentrations, plateau force increased proportionally to the solution concentration. In samples with different flow stresses, a linear relationship was found between the flow stress and the plateau force. Therefore, plateau force may correspond to the flow stress of the material. Alkaline corrosion of aluminum samples lead to formation of nanoscale concave scallops on the surface. The size evolution of the concave scallops as a function of alkaline exposure was characterized with the SEM imaging. Size evolution of scallops corresponded with tensile stress buildup in the samples. The correspondence between the surface morphology evolution, stress buildup and flow stress indicates that corrosion reactions may be associated with plastic flow.

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